**Title: Stringing the Solar System**

**Brief Overview:**

Students will use mathematical conversion methods and scaling in order to calculate and construct a model of the solar system to gain an understanding of proportionate distances between planets, as well as proportionate sizes of the planets. Students will extend their abilities to apply these skills by answering additional challenges that involve conversion.

**Links to NCTM Standards:**

- **Mathematics as Problem Solving**
  Students will use the conversion skills to pursue answers to challenges in the extension activities. Students will represent the solar system concretely, numerically, and verbally, with the possibility of public presentation or display of their models.

- **Mathematics as Communication**
  Students will communicate within their working groups concerning the pros and cons of the English versus metric system in their attempts to convert to measurable data. The problem solving of the challenge questions will involve sharing of their individual formulations of the steps in deriving the solutions.

- **Mathematics as Reasoning**
  Students will reason to operations involved in changing from one unit or scale to another prior to using the method of conversion factors and dimensional analysis.

- **Mathematical Connections**
  Astronomy involves innumerable observations of the universe. Students will recognize that understanding astronomical events and bodies requires the use of mathematics and analysis of numerical data and measurements.

- **Number and Number Relationships**
  Prior to constructing the model, students will estimate the relative distances of the planets from each other and the sun, based on the initial data. They will use the relationships in sizes of numbers and the use of powers of ten in estimation.

- **Number Systems and Number Theory**
  Students will create conversions in both the English system (miles) and metric system (kilometers). Since calculations will result in decimal numbers, they will need to estimate and change decimals to equivalent fractions to use the foot ruler.

- **Computation and Estimation**
  Students will be required to estimate and predict how their models will look. They must employ computation, mainly multiplication and division, to convert to other units.

- **Patterns and Functions**
  A study of the planets and relative orbits and sizes historically led to the discovery of Kepler's laws. A discussion of the patterns observed in orbiting bodies can lead to future lessons, such as the formation of a system from a spinning cloud of cosmic material.

- **Algebra**
  Conversions may also be approached through the setup and solution of proportions, requiring algebra to solve for the unknown quantity.

- **Measurement**
  In order to create a scale model representing their findings, students will make accurate measurements of their conversion results on a string. They should use both feet as a unit and meters. From this experience they can better discuss the advantages of the metric system since converted numbers will result in decimals.

**Grade/Level:**

Middle School (Grades 6-8)

**Duration/Length:**

Five 45 minute class periods

**Prerequisite Knowledge:**

Students should have working knowledge of the following skills:

- Understanding equivalents between units in English and metric systems
- Knowing the names of the planets
- Ability to compute with fractions
- Ability to search the Internet

**Objectives:**

Students will:

- use mathematical conversion methods and scaling to design and construct a model of the solar system.
- estimate from initial data and relate sizes of numbers to each other.
- experience concretely and visually the proportionate distances between planets, as well as the sizes of the planets.
- measure accurately and compare their results to a standard.
- collaborate with classmates to collect accurate data and construct their models.
- extend their abilities to apply these skills by answering additional challenges that involve conversion.

**Materials/Resources/Printed Materials:**

- Non-stretching string
- Scissors
- Pens/Pencils/Paper
- Masking tape
- Rulers
- Meter sticks
- Posterboard/Cardboard
- Colored markers
- Aluminum foil

- Calculators
- Computers with Internet hook-ups

Suggested printed materials:

- "Charting the Planets" (EB-111), an educational brief distributed by NASA, is highly recommended. It is suggested that this resource be used **after** Internet searches are completed to fill in missing information and check findings. This resource provides a chart of physical constants of the planets, activities, a worksheet to be completed, illustrations of relative sizes of the planets.
- "Star Date: Guide to the Solar System" a publication available from NASA or University of Texas at Austin, McDonald Observatory, 2609 University ave., #3.118, Austin, TX 78712
- A "Solar System Lithograph Set," an educational product of NASA for k-12. (EP-338)

Note: NASA's homepage website is http://www.nasa.gov/
NASA Spacelink is at http://spacelink.msfc.nasa.gov

**Development/Procedures:**

Day One: Using the Internet, students will collect data (distance from the Sun and radii) in English and metric systems.
Teachers will introduce the AU (astronomical unit) and scale factor for marking string.
NOTE: One AU is equivalent to the distance from the earth to the sun or 93,000,000 miles. 1 A.U. = 93,000,000 miles.
Students will convert distances to AUs.

Day Two: Teachers will introduce the conversion factor/dimensional analysis method of conversions.
Students will mark string using bits of colored masking tape or markers.

Day Three: Students will use posterboard and cardboard, as well as decorative materials, to create planets to scale.
**WARNING*: Do not attach planets to string at this time.

Day Four: Students will present their representations to the class, and the class will physically compare group results (string markings) by stretching them side-by-side, while discussing variation, precision, and accuracy.
NOTE: Accuracy denotes correctness and how true the value is to the correct measurement. Precision denotes how small a unit the measurements are in, e.g., 1.2 ft. is more precise than 1 ft. Precision also can be understood to be how close together repetitions of the same measurements are.

Day Five: Teachers will provide students with challenges utilizing conversion factor/dimensional analysis as extension activities.

**Performance Assessment:**

The teacher should pre-prepare his/her own accurately measured and marked model. Student models can be compared and scored against the teacher model. Points can be scored based on deviation from the standard. Refer to attached sample scoring tool.

## Extension/Follow Up:

Challenge Questions:

- How many miles of string would each group need in order to represent the nearest star system to our Sun, using the scale of 1 AU equals 1 scale foot?*

- How many kilometers of string would each group need in order to represent the nearest star system to our Sun, using the scale of 1 AU equals 1 scale kilometer?

- Calculate the distance of a light year starting with the speed of light in both miles and meters. Express your answer both in normal and scientific notation.

- (If students have learned algebra and formula use) If a satellite orbits the earth at 17,500 miles/hour in 1 1/2 hours, at what height above the earth's surface is it orbiting? Search your materials or the Internet to find and use the circumference of the earth.

Sample of conversion factor/dimensional analysis method:

Facts needed:
Speed of light = 186,000 miles/sec
Nearest star system is Alpha Centauri at 4.3 light years.

| Equivalents needed: | Conversion factors: |
|---|---|
| 1 year = 365 days | $\frac{1\text{ year}}{365\text{ days}}$ or $\frac{365\text{ days}}{1\text{ year}}$ |
| 1 day = 24 hrs | (see above form) |
| 1 hr = 60 min | (see above form) |
| 1 min. = 60 sec. | (see above form) |
| 1 A.U. = 93,000,000 miles | (see above form) |

Scale factor:
1 ft string = 1 A.U.

Solution:

$$1\text{ light year} = \frac{365\text{ days}}{\text{year}} \times \frac{24\text{ hrs}}{\text{day}} \times \frac{60\text{ min}}{\text{hour}} \times \frac{60\text{ sec}}{\text{min}} \times \frac{186{,}000\text{ miles}}{\text{sec}}$$

= 5,900,000,000,000 or 6 trillion miles 6 x 10^12 miles

To solve amount of string needed to represent Alpha Centauri:

$$\frac{4.3\text{ lt yrs}}{1} \times \frac{6\text{ trillion miles}}{\text{lt.yr.}} \times \frac{1\text{ A.U.}}{93{,}000{,}000\text{ miles}} \times \frac{1\text{ ft string}}{1\text{ A.U.}} \times \frac{1\text{ mile}}{5280\text{ ft string}}$$

Answer: 52.5 miles string to represent distance to nearest star

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# Sample Scoring Tool

**Team Name:** ________________ **Team Members:** _____________________
_____________________
_____________________
_____________________

| **Planets** | **Discrepancy with Teacher's Model**<br>(Use(+) to denote measurement is too large)<br>(Use (-) to denote measurement is too small) |
|---|---|
| Mercury | -4 inches (measurement was not large enough between Sun and Mercury, for example) |
| Venus | Measure between Venus and Mercury |
| Earth | Measure between Earth and Venus |
| List all the planets | Measure between the planets |

The total score is found by adding the absolute values of the discrepancies. There will be a multiplier effect since one measurement will throw off all the next ones. However, if all teams follow the same scoring rubric, the high and low standings should remain the same.

Absolute values are used in summing the total results since positive numbers might cancel the negative results, giving an invalid total discrepancy.

Teams can check other team results. This leads to a discussion of percent error and why some per cent error calculations are positive and some are negative. Algebraically, the difference between experimental results and theoretical (teacher's model) results will come out either positive or negative depending on whether the experimental results are less than or greater than the theoretical since:

$$\% \text{ error} = \frac{\text{experimental} - \text{theoretical} \times 100}{\text{theoretical}}$$

The teacher could add to the rubric an artistic component. Each team could rate the other models on a scale of 1 to 10 assessing the creativity and display qualities. Suggest that the students themselves come up with the criteria for judging. To add interest, make this a contest and bring in another teacher to decide the winner. It is important that there be an audience for the student work to build pride and incentive. Display the models from the ceiling of the hallway(s).